Tevatron 2014 Impact on NOνA

Fermilab PAC

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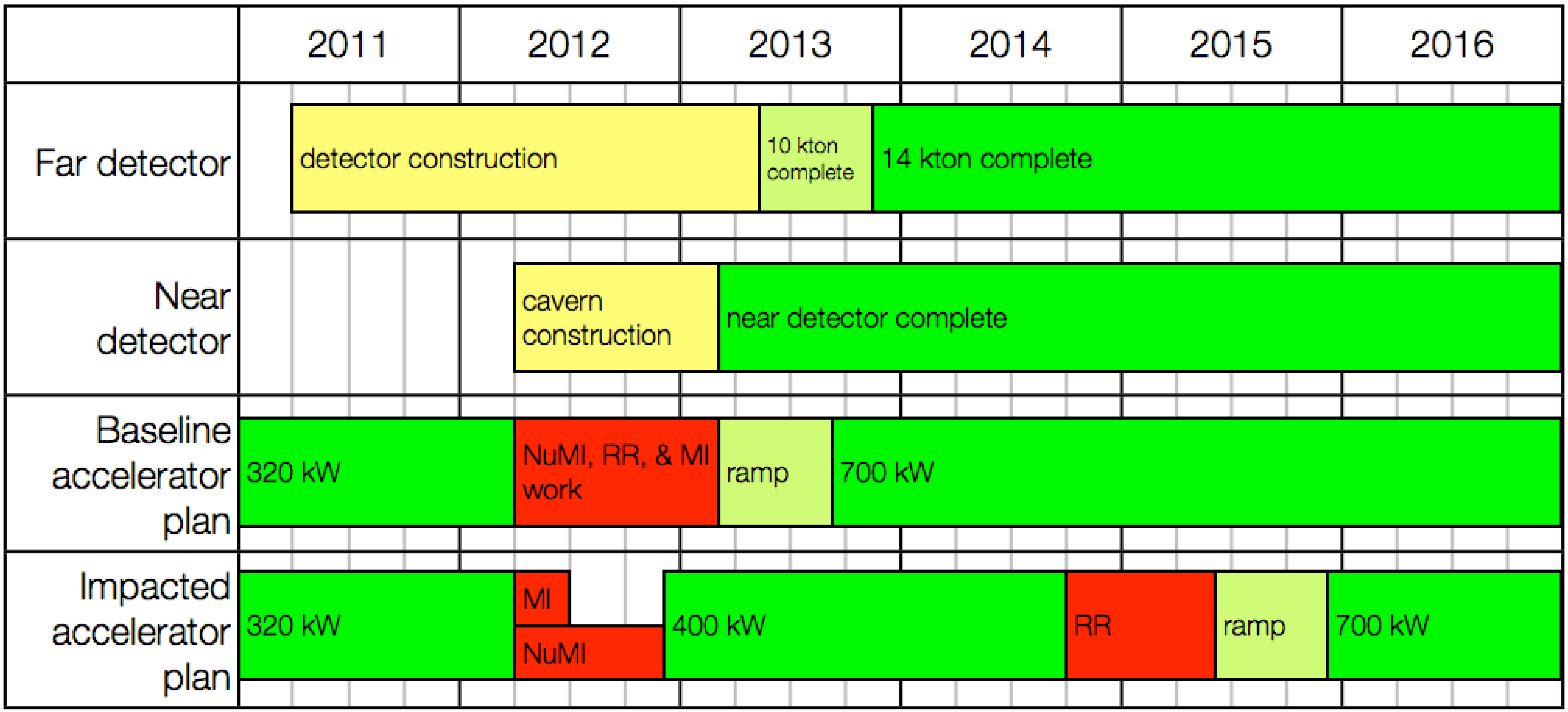
Impact Summary

- Impact of Tevatron 2014 on NOνA:
  - Reduce the NOνA data set by roughly a factor of 2 in the 2015-2016 time period.
  - Delay first results on ν_μ antineutrino oscillations by 2 years.
  - Delay first results on mass ordering and the CP-violating phase by 2 years.
  - Delay the final results by 1.5 years.
  - Add an additional 3.7 M$ to the cost of the project.

Scenarios


2011
2012
2013
2014
2015
2016
Far detector
detector construction
10 kton complete
14 kton complete
Near detector
cavern construction
near detector complete
Baseline accelerator plan
320 kW
NuMI, RR, & MI work
ramp
700 kW
Impacted accelerator plan
320 kW
MI
NuMI
400 kW
RR
ramp
700 kW

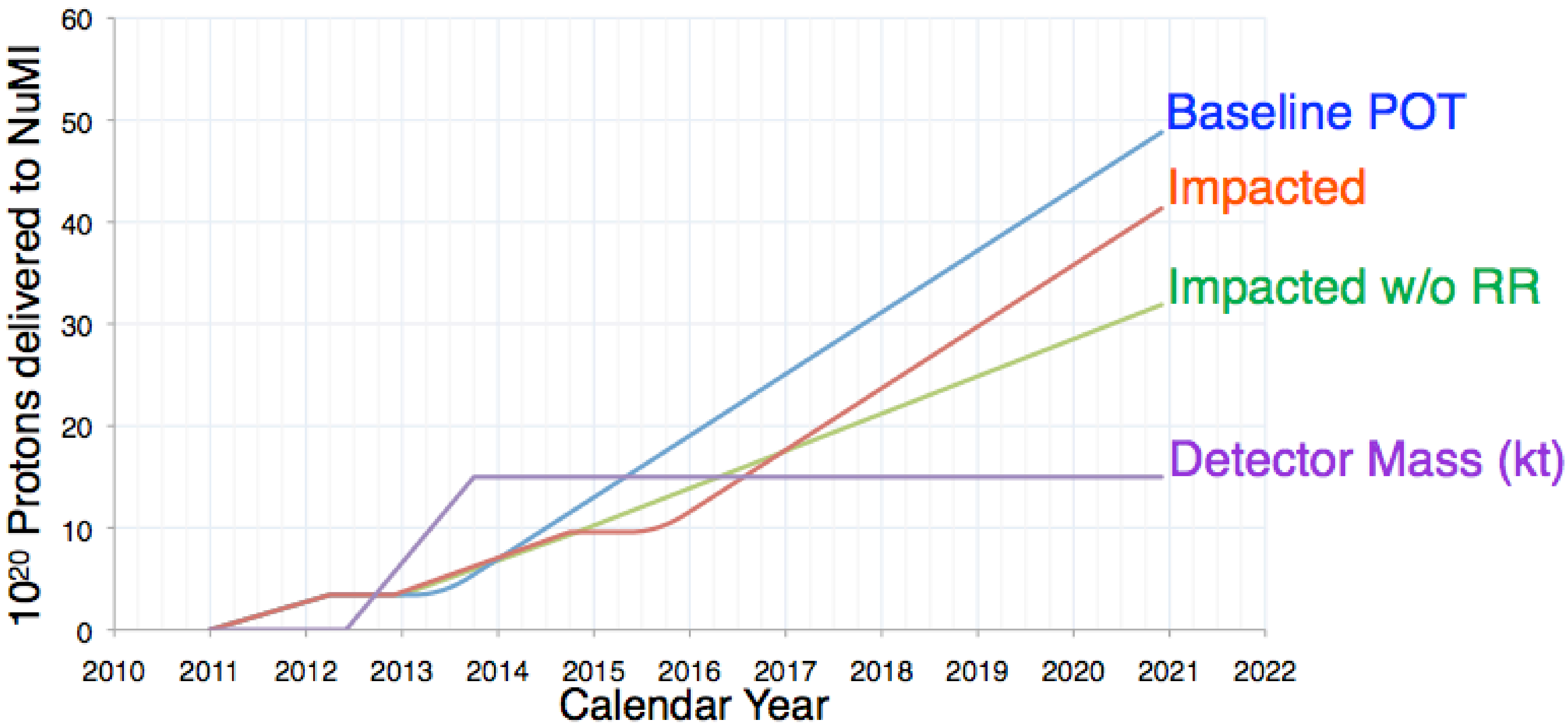
Why 400 kW?

- This is consistent with the present limit of 320 kW and consistent with the 700 kW NOνA baseline.
- 320 kW → 400 kW is due mainly to two ~10% effects: a decrease in the cycle time from 2.2 to 2.0 s and interleaving cycles so that NOνA gets an average of 10 Booster batches instead of 9.
- 400 kW → 700 kW is also due to two effects: a decrease in the cycle time from 2.0 s to 1.33 s and an increase in the number of Booster batches from 10 to 12.

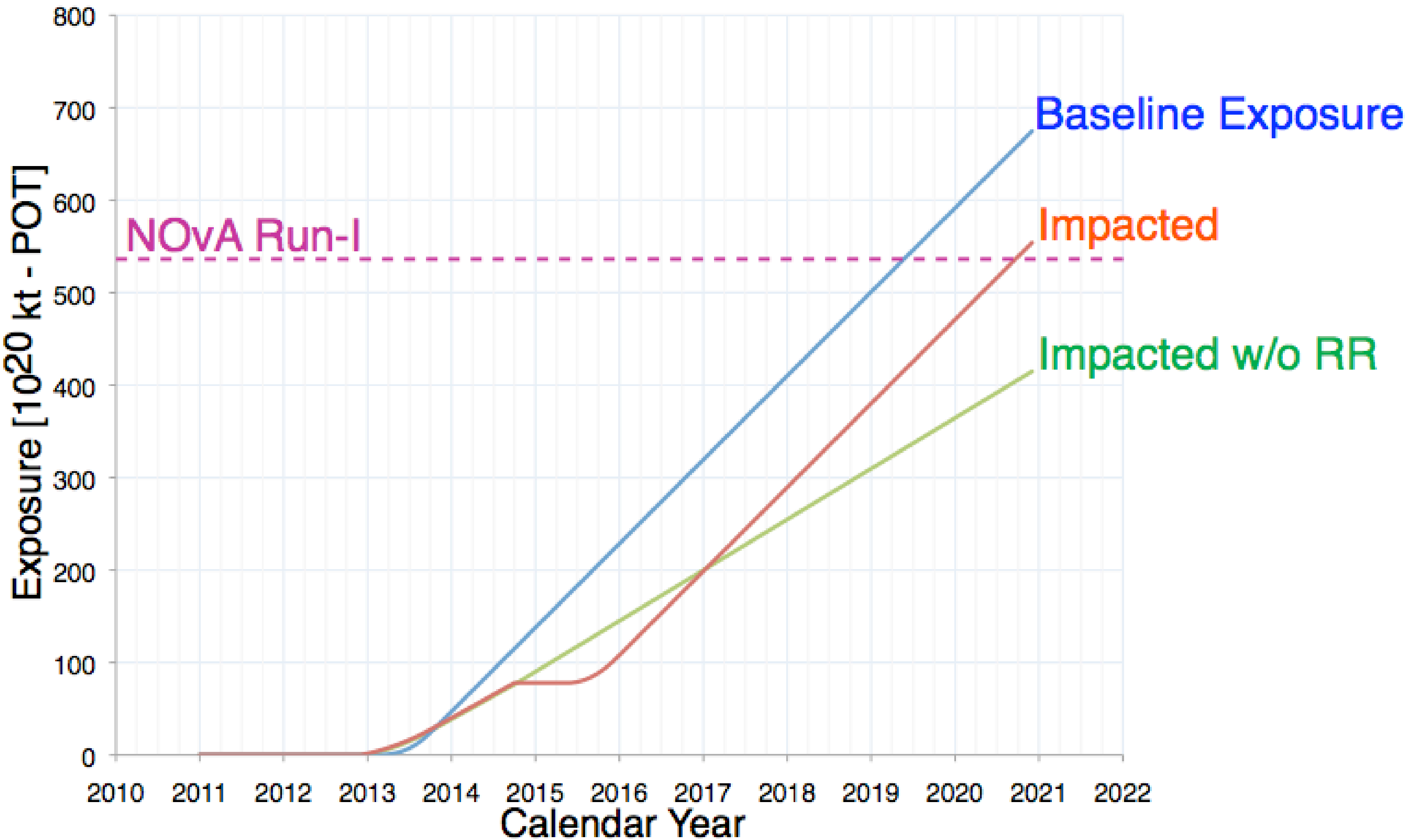
Detailed Power Assumptions

	Baseline	Run IIc
Booster batch Intensity (e12)	4.3	4.3
Average number of NOνA batches	12	10
MI efficiency	0.95	0.95
Average NOνA Intensity (e12)	49	41
Fill period (s)	0	0.67
Base cycle time (s)	1.33	1.33
Total cycle time (s)	1.33	2.00
NOνA Power (kW)	706	392

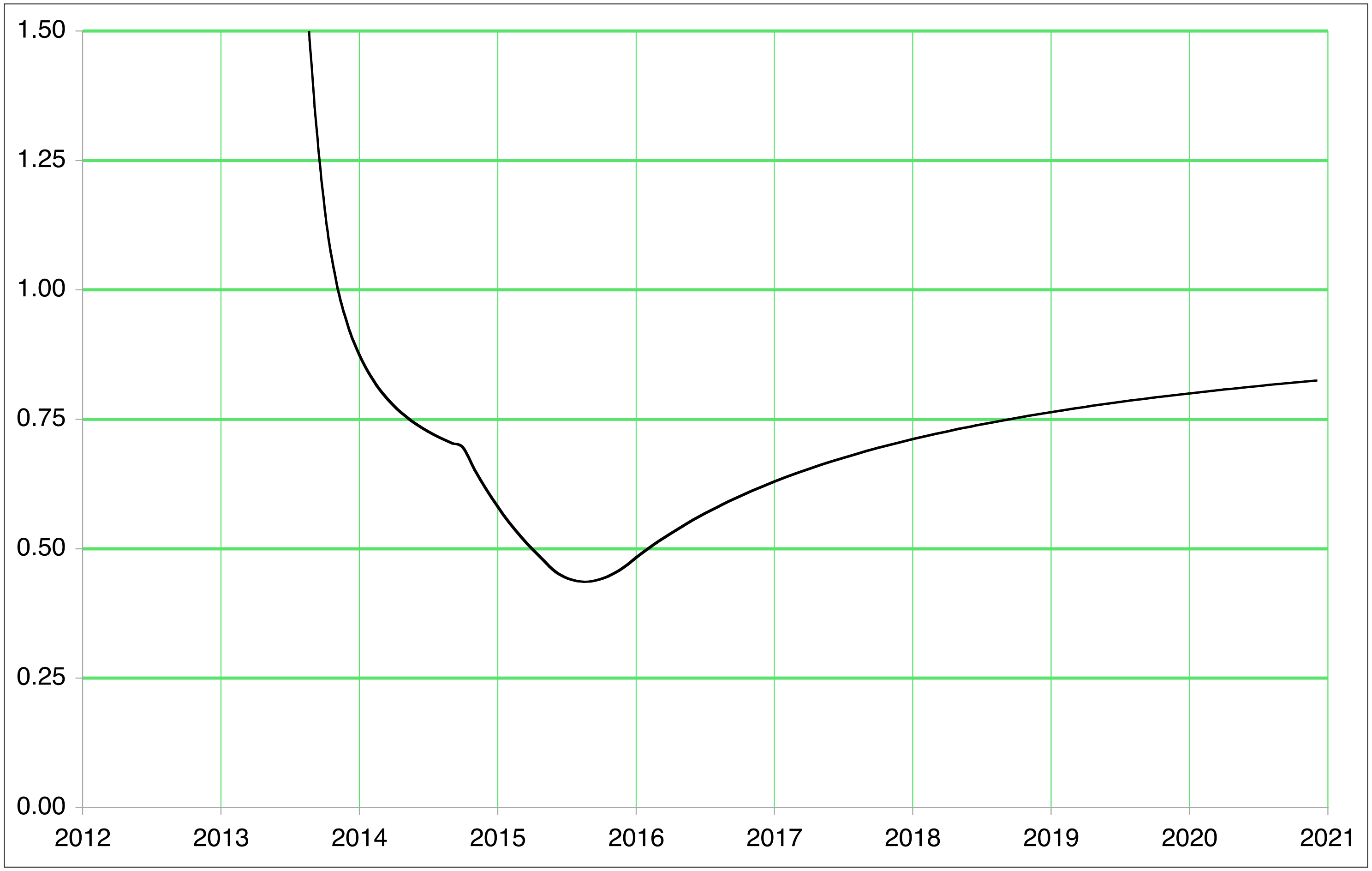
Integrated POT & Detector Mass



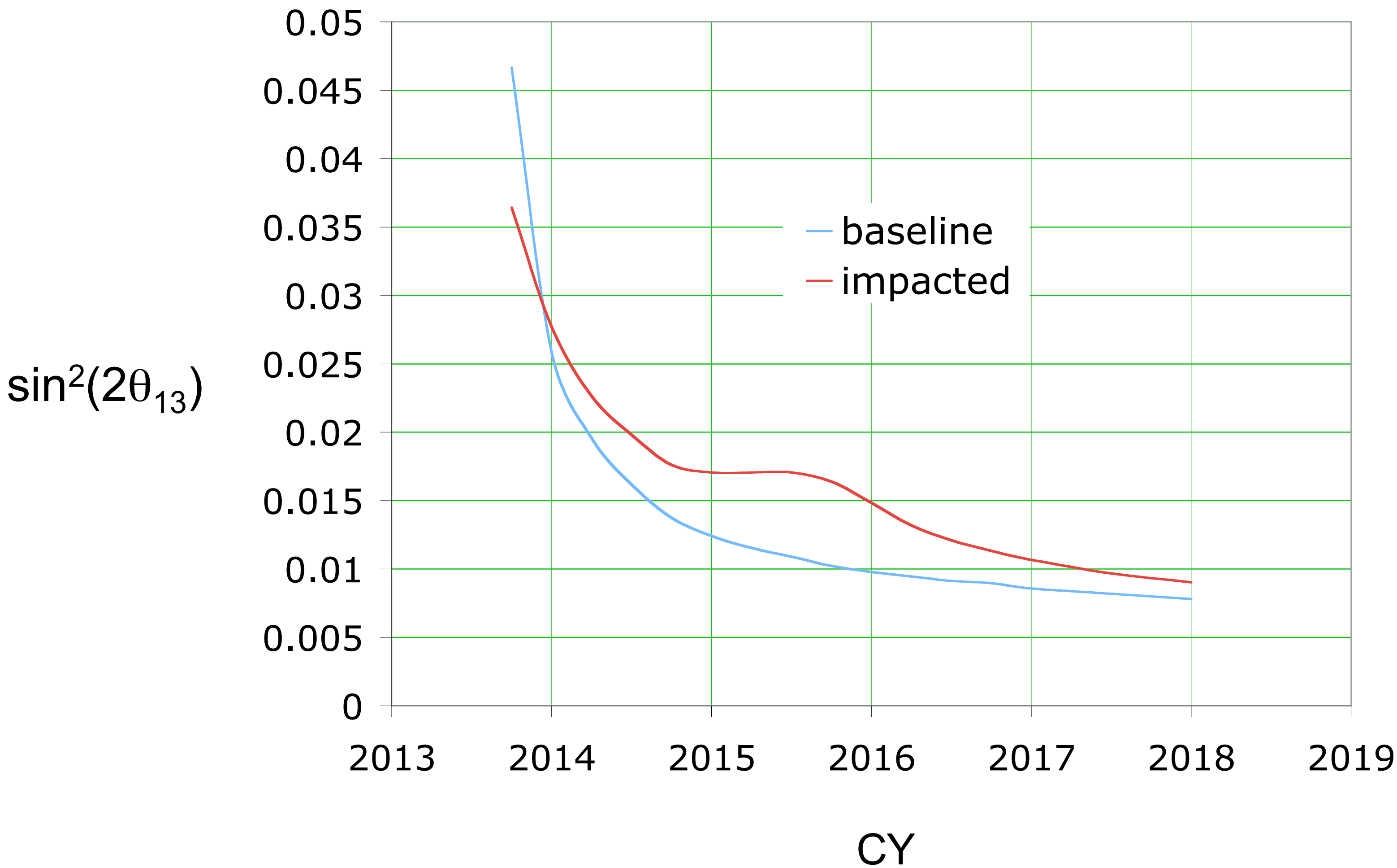
Integrated (POT × Detector Mass)



Ratio Impacted / Baseline



90% CL Sensitivity to $\sin^2(2\theta_{13})$



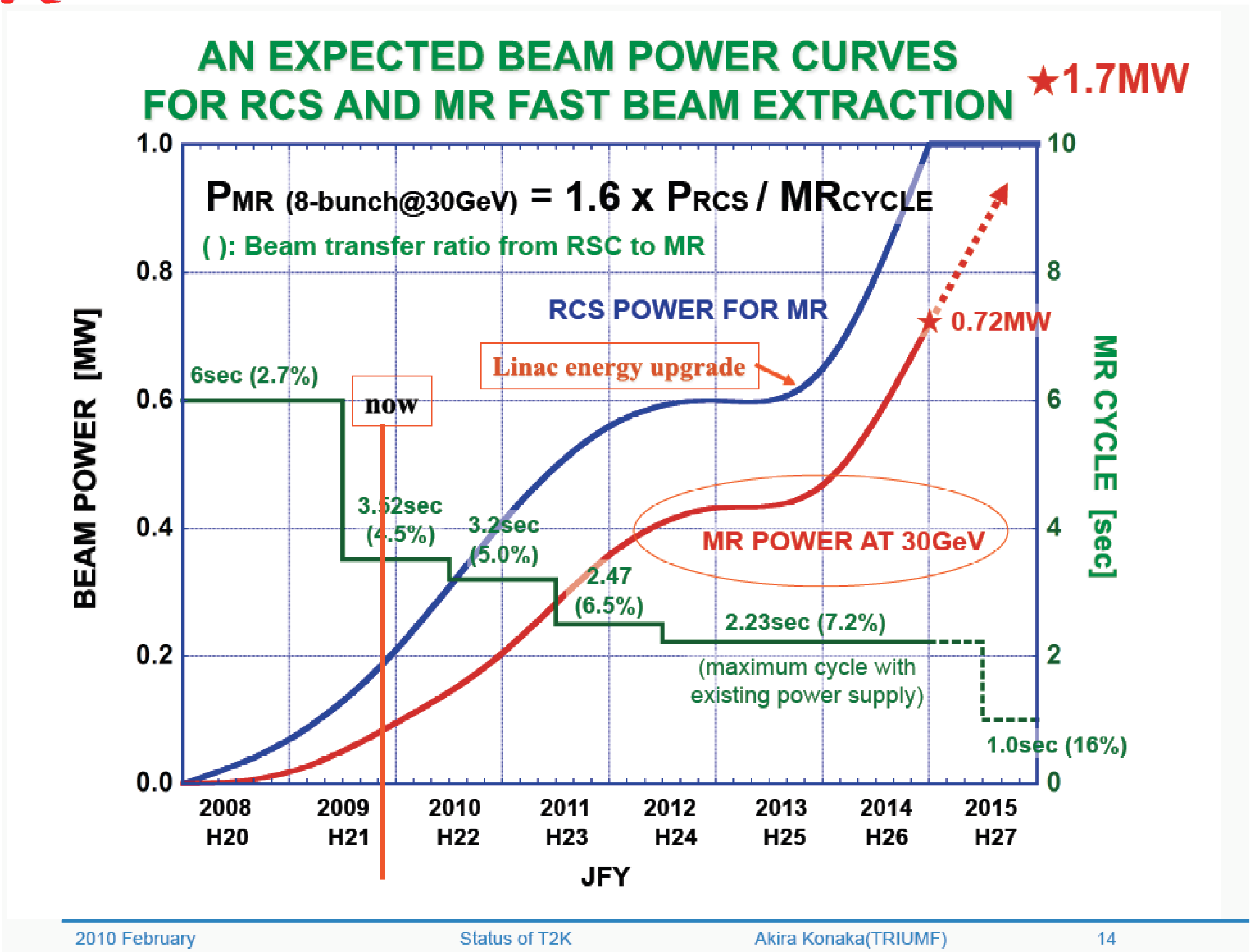
Other Experiments: Reactors

- Reactors: Three reactor experiments will report results in the 2014 time frame (or sooner): Double Chooz, RENO, and Daya Bay.
  - Reactors do not measure the same thing as accelerator experiments.
    - Reactors measure $\sin^2(2\theta_{13})$.
    - Accelerators measure a complex combination of $\sin^2(2\theta_{13})$, $\sin^2(\theta_{23})$, the CP-violating phase δ, and the mass ordering. If all these effects go in the same direction, the oscillation rate in reactors and accelerator experiments can differ by a factor of 2.5.
  - Thus, a comparison of reactor and accelerator results is informative.

Other Experiments: T2K

- T2K is the only other accelerator experiment in this time frame. It should measure the identical oscillations as NOνA except for matter effects, which are used to determine the mass ordering. These effects are 2.7 times larger in NOνA than in T2K.
- T2K is running now, but at low power. They are projecting a slow ramp-up of power (next slide).

T2K Power Projections



Estimated Sensitivities

90% CL for $\sin^2(2\theta_{13})$ at the end of CY 2014

Experiment	Sensitivity
Double Chooz	0.03
RENO	0.02
Daya Bay	0.009
T2K	~~0.02~~ 0.01
NOνA baseline	~~0.011~~ 0.012
NOνA impacted	~~0.015~~ 0.016

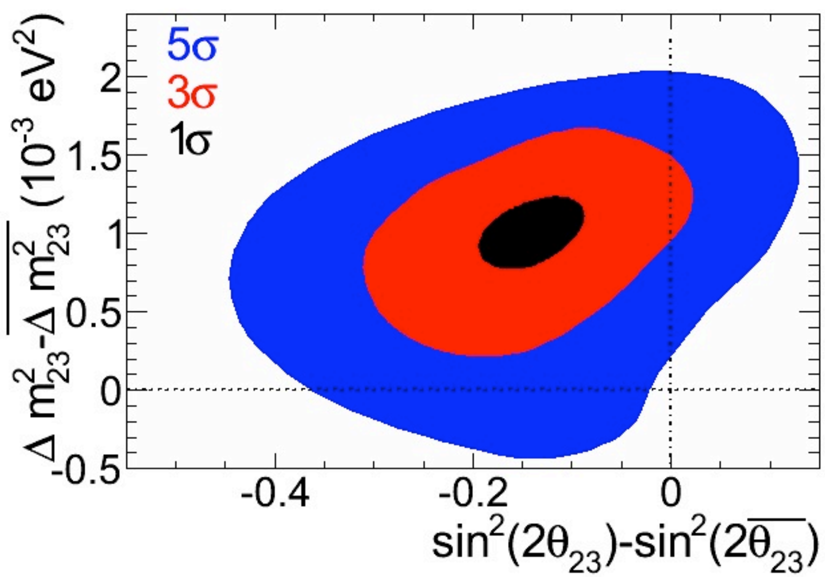
Warning: 90% CL Gaussian calculation at the sensitivity level does not mean much for NOνA and T2K. Both would have only a handful of events, e.g. 2.8 signal on a background of 2.5 for NOνA.

Antineutrinos

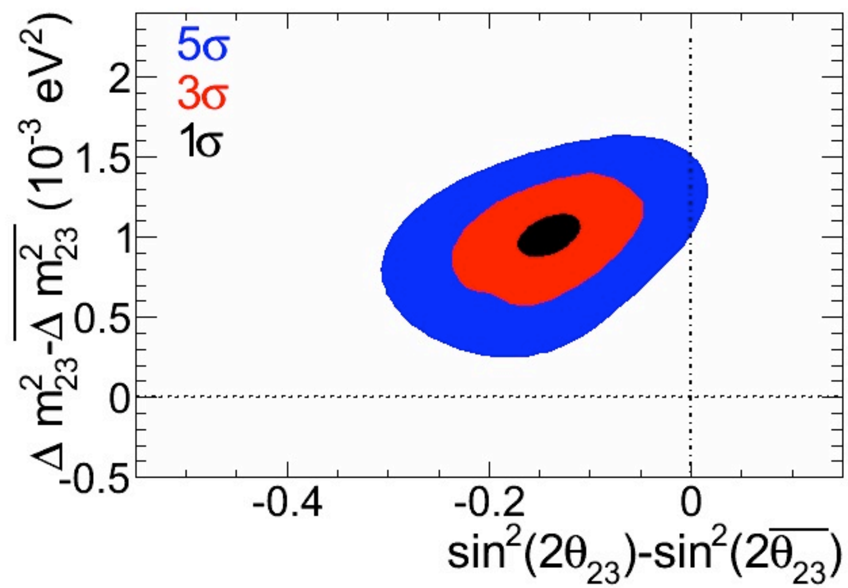
- The major rationale for the NOνA experiment is not to measure $\sin^2(2\theta_{13})$, but to compare neutrino and antineutrino oscillations to gain information on the mass ordering of neutrinos and CP violation.
- A difference in neutrino and antineutrino ν_μ disappearance oscillations would be a sign of beyond-the-standard-model physics.
  - There is currently an about 2-σ effect seen my the MINOS experiment. If this persists into the NOνA era, NOνA will be able to easily confirm or rebut the effect.

NOνA Sensitivity to the MINOS Effect

1 year each ν and $\bar{\nu}$



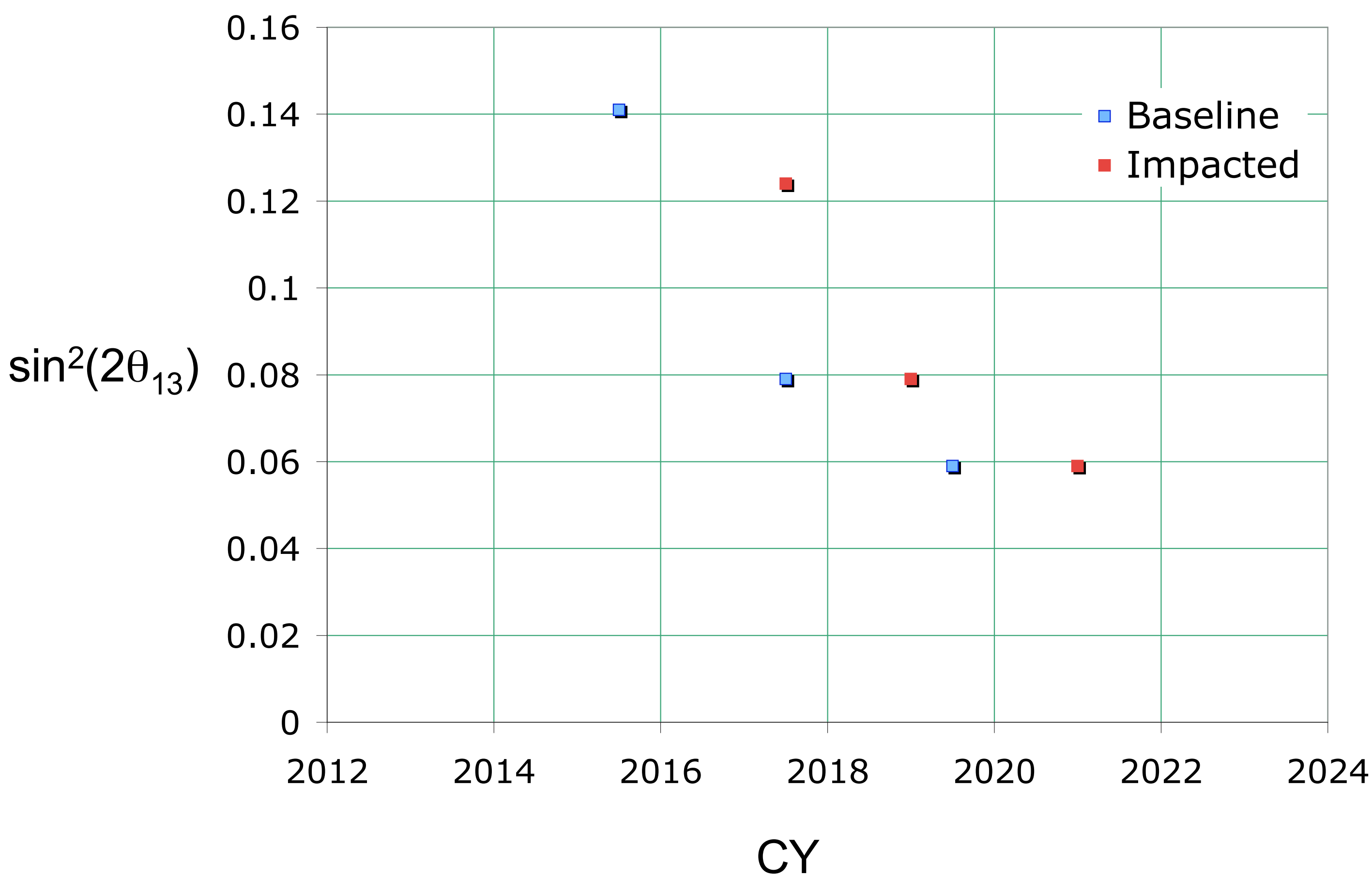
3 years each ν and $\bar{\nu}$



Impact on Antineutrino Running

- NOνA would normally start running antineutrinos after one year of neutrino running, provided it had seen a believable $\nu_\mu \rightarrow \nu_e$ signal by then. In the baseline scenario, this would be in June 2014.
- In the impacted scenario, this point would come at the end of 2015, just as we were finishing commissioning the 700 kW beam. We would then want to delay switching to antineutrinos for six months to assure ourselves that the 400 kW and the 700 kW configurations gave the same results. Thus, we would not start antineutrino running until mid 2016, a two year delay.

95% CL Determination of the Mass Ordering at the Most Favorable δ



Additional Cost of Delaying NOnA’s CD-4

- There would be at least a 1-year delay in reaching CD-4. We estimate the additional cost to be 3.7 M$:
  - 1.1 M$ for escalation on the delayed modifications to the Main Injector and Recycler.
  - 2.6 M$ for continued, but reduced, project management.

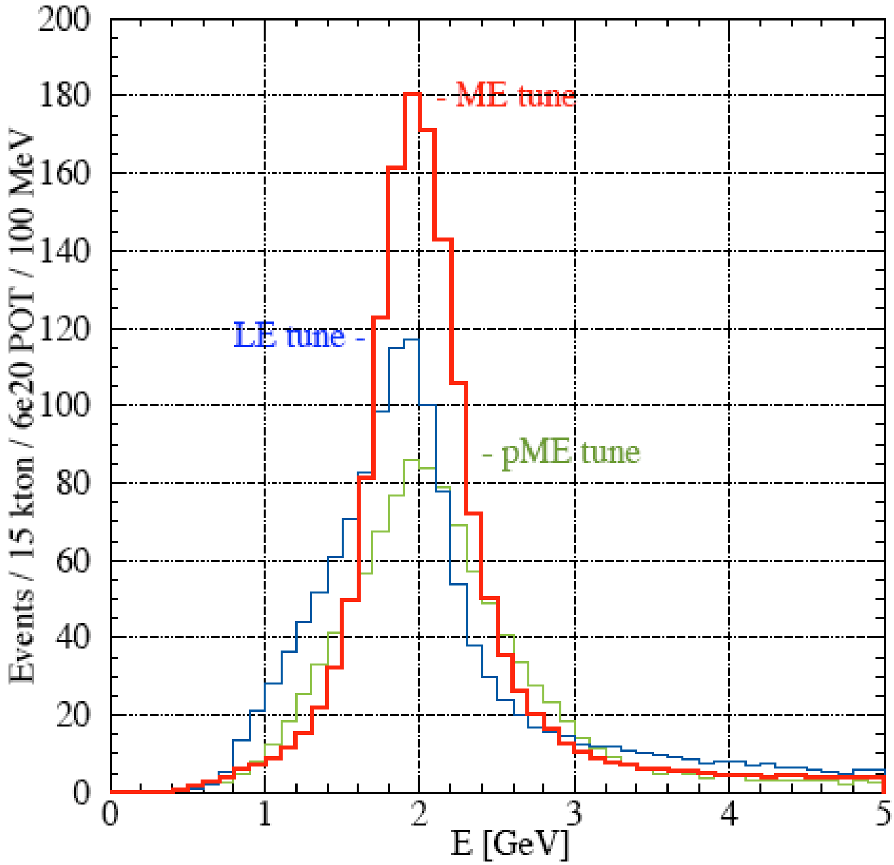
Conclusion

- NOνA is the flagship US accelerator experiment for the 2010-2020 decade. It is also the first step in the future US intensity frontier program.
- It was already delayed a year due to the disastrous omnibus funding bill in December 2007. However, it is still competitive with the other second-generation experiments in the field due to slips in their schedules.
- Delaying it further would
  - Make it less relevant in the time period when all experiments will be reporting significant results.
  - Reinforce the impression abroad that the US is not a reliable partner.

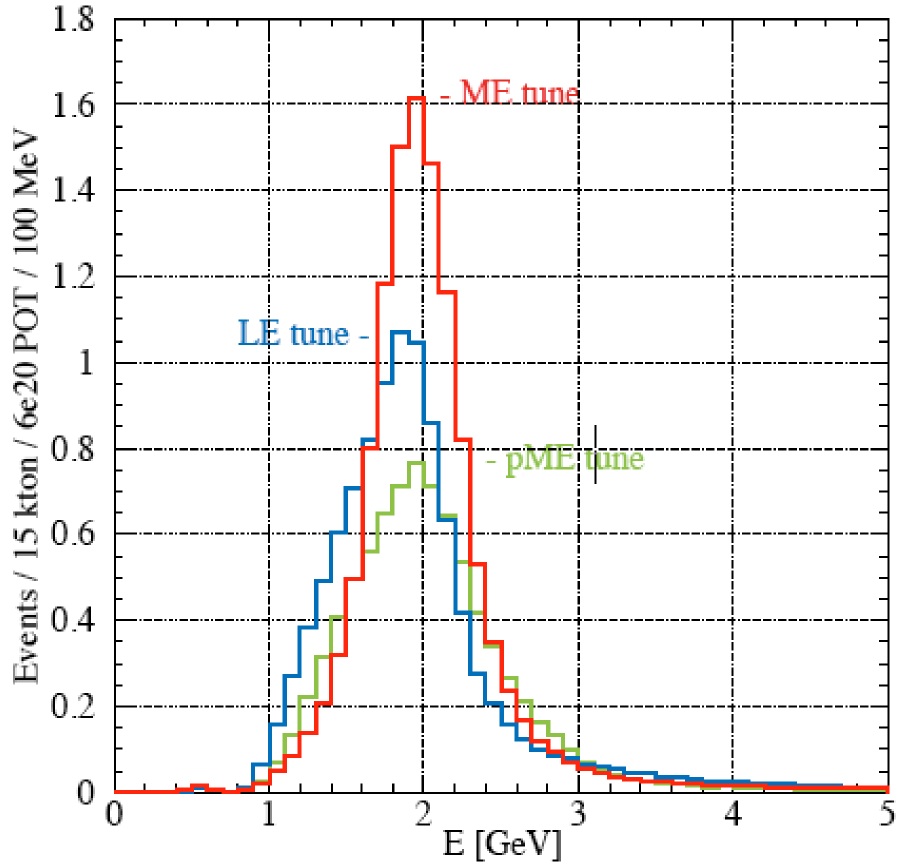
Backup

Horn and Target Tunes

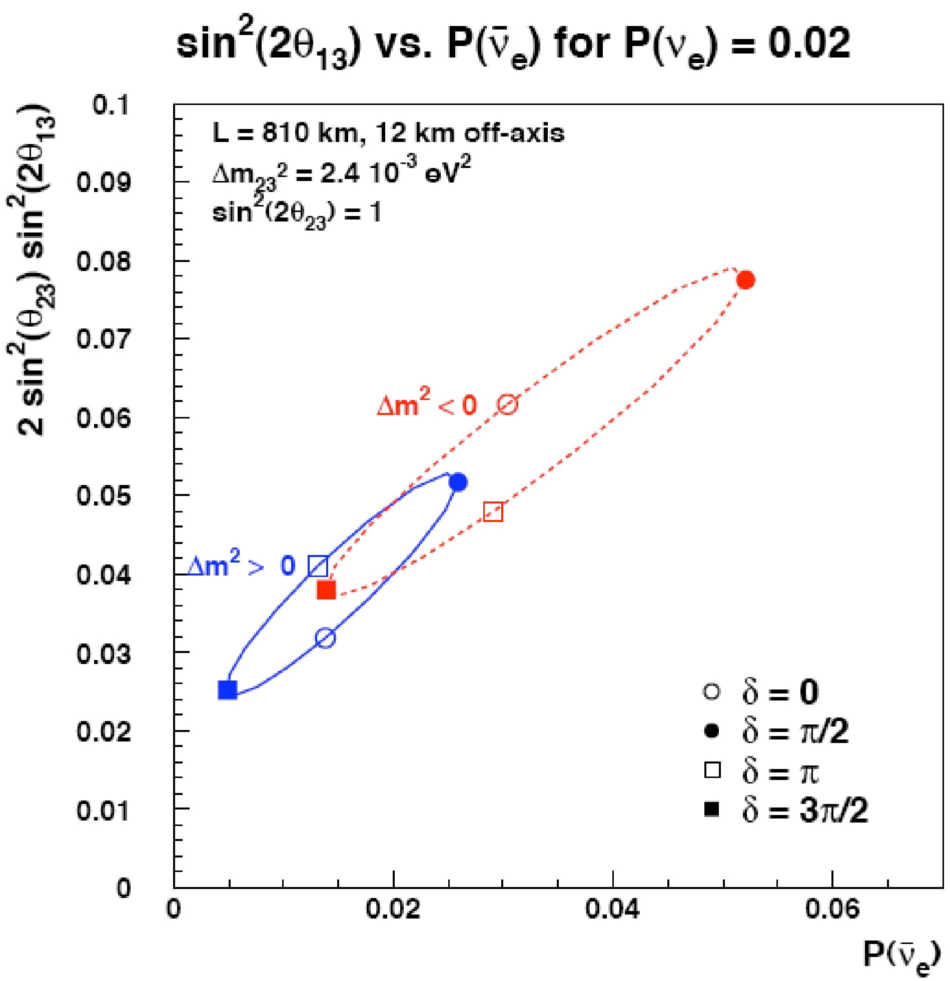
Unoscillated ν_μ



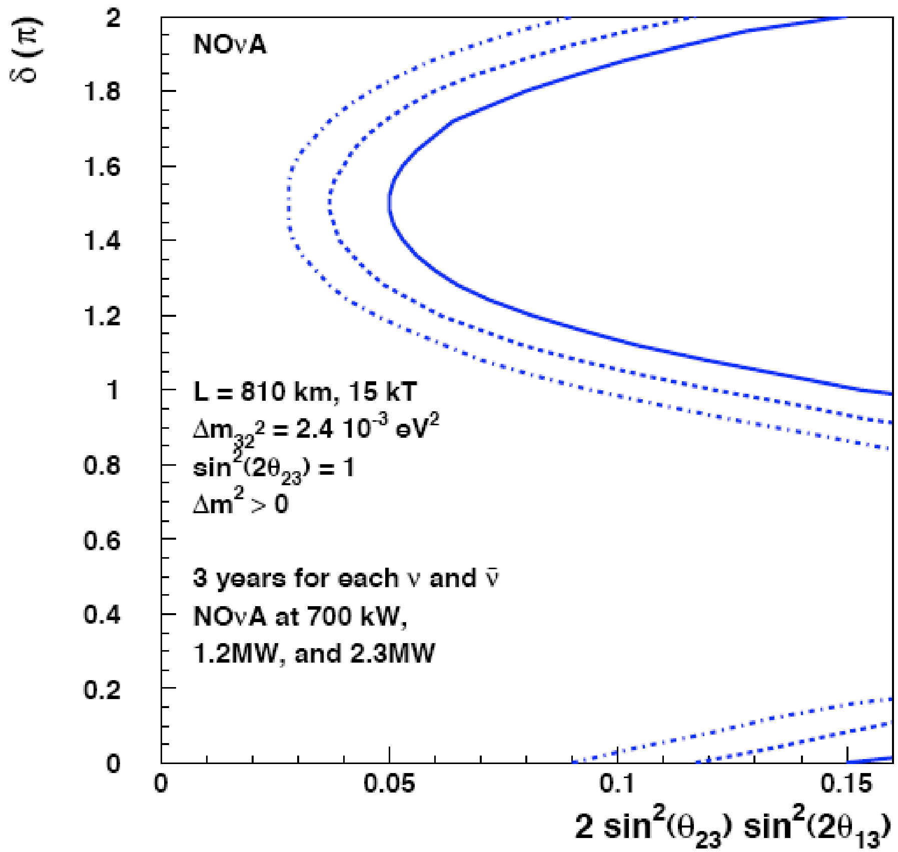
$\nu_\mu \rightarrow \nu_e$, $\sin^2(2\theta_{13}) = 0.01$



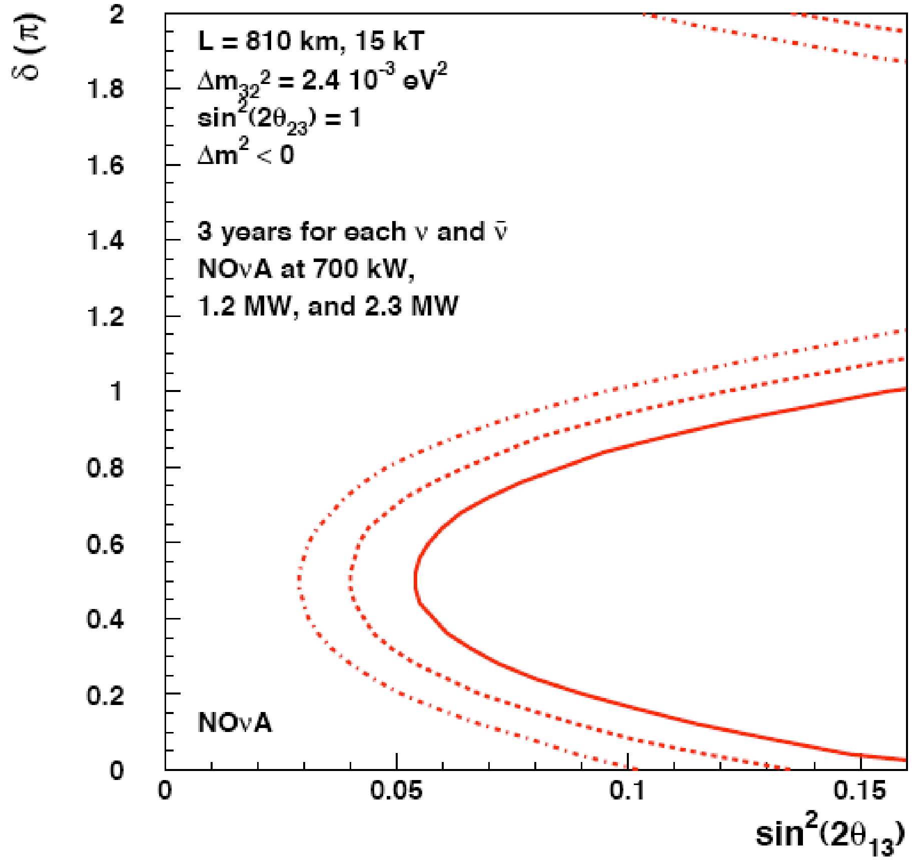
Parameters Consistent with a 2% $\nu_\mu \rightarrow \nu_e$ Oscillation Probability



95% CL Resolution of the Mass Ordering NOνA Alone

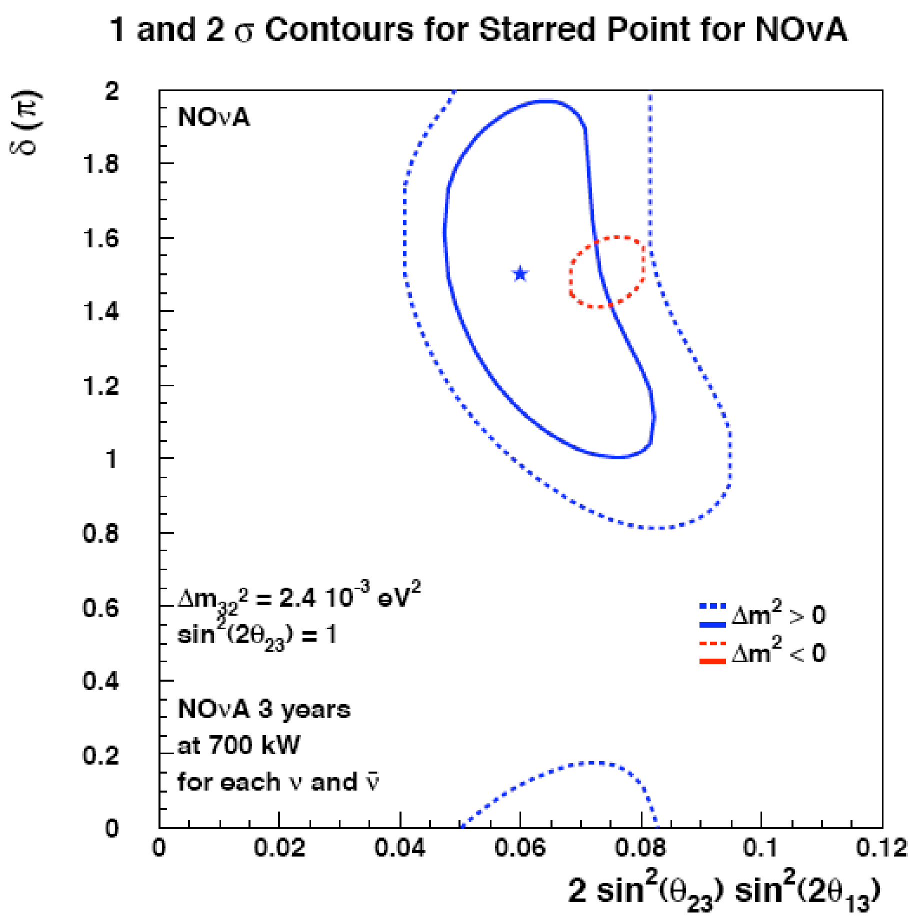


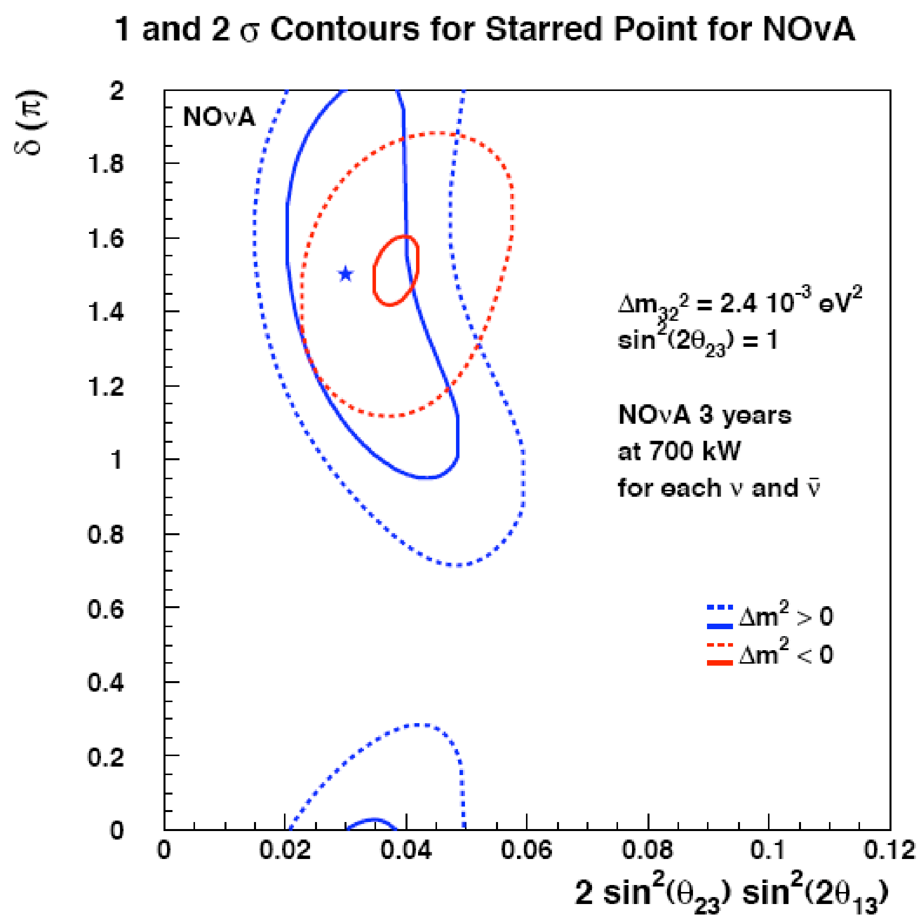
Normal Ordering



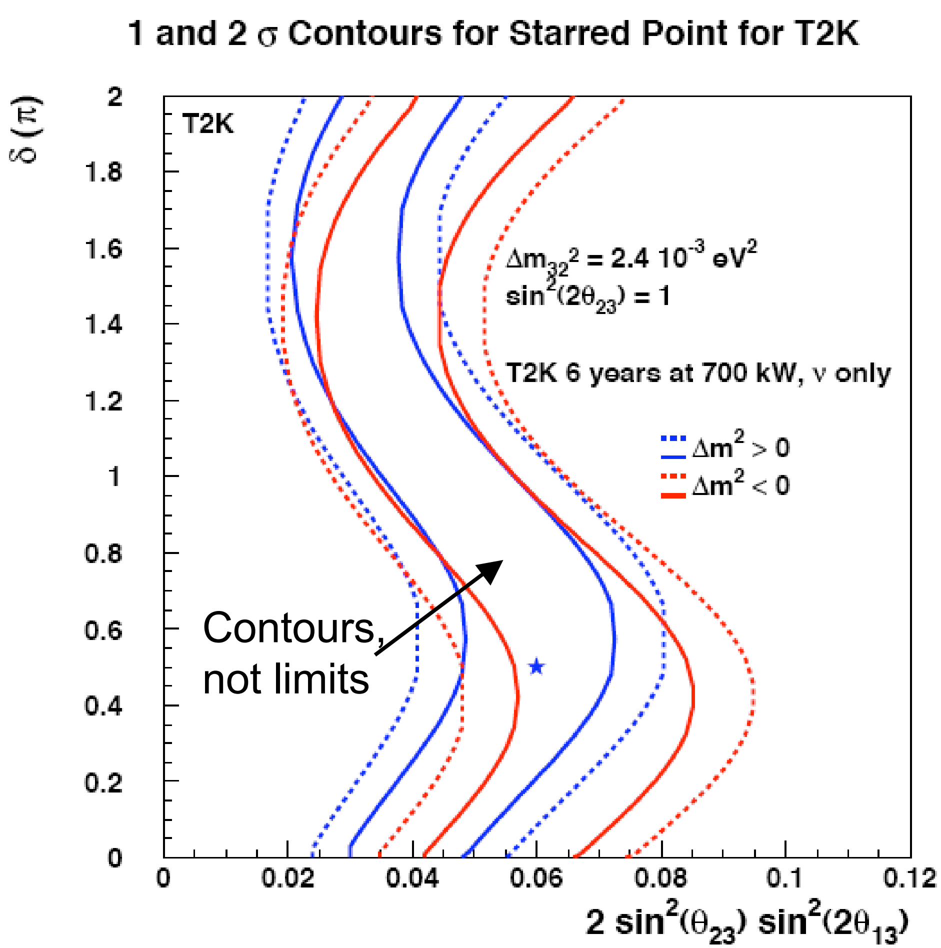
Inverted Ordering

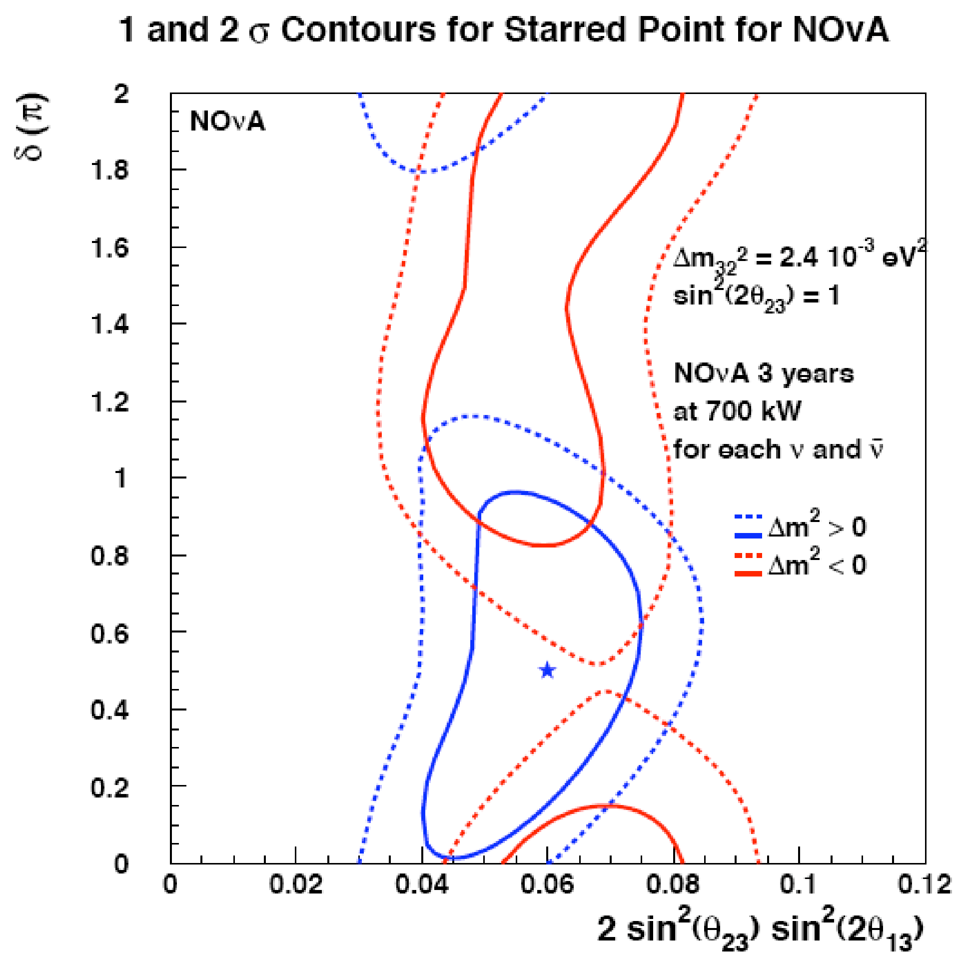
δ vs. θ_{13} Contours: Best Possible δ





δ vs. θ_{13} Contours: Worst Possible δ T2K and NOνA Alone





δ vs. θ_{13} Contours: Worst Possible δ T2K and NOνA Combined